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Technology-Enhanced Learning in the COVID-19 Era: A Systematic Review of Online Education Platforms, Student Engagement, and Digital Equity

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Abstract

The rapid, largely unplanned shift to online and remote instruction that accompanied the COVID-19 pandemic in 2020 accelerated more than a decade of gradual educational technology (EdTech) adoption into a matter of weeks, making 2021 a pivotal moment for taking stock of what a full decade of research had, and had not, established about technology-enhanced learning. This paper presents a systematic review and bibliometric synthesis of research on online learning platforms, student engagement, and digital equity published between 2010 and 2021. Following PRISMA-guided screening of 4,204 records identified across Scopus, Web of Science, ERIC, and IEEE Xplore, 172 studies met inclusion criteria and formed the analytic corpus. Bibliometric mapping of publication trends, leading journals, contributing countries, and keyword co-occurrence networks was combined with thematic synthesis of application types, benefits, and challenges. Results show a slow, steady growth in online-learning research through 2019 followed by an unprecedented spike in 2020–2021 coinciding with global school and university closures. Learning management systems, video-conferencing platforms, and mobile learning applications were the most frequently studied technologies, while the most consistently reported benefits concerned flexibility and access, and the most consistently reported challenges concerned the digital divide, teacher readiness, and diminished student engagement. The review synthesizes these findings into an integrated model of technology-enhanced learning adoption and outlines a research agenda emphasizing equity-oriented implementation, hybrid pedagogical design, and longitudinal evidence on learning outcomes. All literature synthesized and cited in this review was published between 2010 and 2021, providing a historically bounded account of the decade culminating in education's pandemic-driven digital transformation.

1. Introduction

Educational technology research spent much of the 2010s building a steady, largely incremental evidence base on online, blended, and distance learning (Means et al., 2013; Moore et al., 2011). Learning management systems matured, massive open online courses (MOOCs) briefly promised to disrupt higher education

(Hew & Cheung, 2014), and mobile and gamified learning tools expanded classroom possibilities (Naciri et al., 2020). Then, in early 2020, the COVID-19 pandemic forced the near-total, simultaneous closure of schools and universities across more than 190 countries, compelling an almost instantaneous shift from a decade of gradual, opt-in technology adoption to compulsory,

system-wide emergency remote teaching (Hodges et al., 2020; UNESCO figures cited widely in Bozkurt & Sharma, 2020).

This abrupt transition generated an unprecedented volume of research within a very short window, much of it produced under significant time pressure and with limited opportunity for the iterative refinement that characterizes mature research areas (Bond et al., 2021; Crawford et al., 2020). By the end of 2021, the field faced a paradox: more had been published on online and remote learning in two years than in the entire preceding decade, yet consensus remained elusive on foundational questions such as which technologies most reliably sustain engagement, how to mitigate the digital divide, and whether emergency remote teaching should be equated with, or clearly distinguished from, genuine online learning (Hodges et al., 2020).

Several narrower reviews addressed specific slices of this literature — emergency remote teaching in higher education (Bond et al., 2021), online teaching and learning research through 2018 (Martin et al., 2020), or COVID-19-specific pedagogy responses (Rapanta et al., 2020) — but few studies have combined systematic review methodology with quantitative bibliometric mapping to characterize the full 2010–2021 decade as a single, historically bounded unit spanning both its gradual pre-pandemic growth and its pandemic-driven acceleration.

This review addresses that gap by asking four questions: (1) How did research output on educational technology, online learning, and digital equity evolve from 2010 to 2021, and which journals, countries, and institutions contributed most? (2) What thematic structure characterizes this literature, as revealed through keyword co-occurrence analysis? (3) Which technologies, benefits, and challenges have received the most sustained empirical attention? (4) What does this decade-long evidence base suggest about priorities for future research on technology-enhanced learning?

2. Theoretical Background

2.1 Defining Online, Blended, and Emergency Remote Learning

Moore et al. (2011) distinguish e-learning, online learning, and distance learning as overlapping but non-identical constructs, differentiated primarily by the degree of physical separation between learner and instructor and the extent of technology mediation.

Garrison and Vaughan (2013) further define blended learning as the thoughtful integration of face-to-face and online instruction, a design choice rather than a stopgap measure. Hodges et al. (2020) later introduced a crucial distinction for interpreting the 2020–2021 literature: emergency remote teaching (ERT) is a temporary shift to alternative delivery necessitated by crisis circumstances, fundamentally different in design intent and preparation time from carefully planned online learning — a distinction this review treats as analytically important when synthesizing findings across the full decade.

2.2 Frameworks for Online Learning Design and Engagement



Figure 1.1. Conceptual ecosystem of educational technology for remote learning.

Anderson's (2011) theory of online learning and Picciano's (2017) integrated multimodal model both emphasize that effective technology-enhanced learning depends on deliberate alignment between pedagogy, social presence, and cognitive engagement, rather than on the technology itself. Student engagement research from this period increasingly disaggregated engagement into behavioral, cognitive, and emotional dimensions, with synchronous and asynchronous delivery modes producing different engagement profiles (Fabriz et al., 2021). Self-regulated learning emerged as a recurring construct explaining why some students thrived in less-structured online environments while others struggled (Garcia et al., 2018).

2.3 The Digital Divide and Equity Perspectives

Warschauer and Matuchniak (2010) offered an influential early framework distinguishing first-level digital divides (access to devices and connectivity)

from second-level divides (differences in digital skills and quality of use), a distinction that proved essential for interpreting inequities exposed by pandemic-era remote learning (Adedoyin & Soykan, 2020). Van Dijk's (2020) broader theorization of the digital divide as a multi-stage process — motivation, access, skills, and usage — was widely applied in COVID-era research to explain why simply distributing devices did not equalize learning opportunity (Mishra et al., 2020).

2.4 Bibliometric Mapping as a Meta-Research Tool

As in other rapidly growing educational technology subfields, bibliometric analysis — publication counts, citation patterns, and keyword co-occurrence mapping — offers a quantitative complement to narrative synthesis, allowing researchers to identify a field's intellectual core and its more peripheral or emerging themes (Bond et al., 2020). Tools such as VOSviewer-style network mapping have been applied specifically to online-learning and educational-technology corpora to trace how thematic emphasis shifted before and after 2020 (Martin et al., 2020).

3. Methodology

3.1 Review Design

This study followed a two-stage design: (a) a systematic literature search and PRISMA-guided screening process to build a bounded corpus of educational-technology and online-learning research published between January 2010 and December 2021; and (b) bibliometric analysis of the resulting corpus combined with thematic synthesis of reported technologies, benefits, and challenges.

3.2 Search Strategy and Data Sources

Four databases were searched: Scopus, Web of Science Core Collection, ERIC, and IEEE Xplore. The search string combined technology-related terms (“online learning,” “e-learning,” “distance education,” “emergency remote teaching,” “blended learning,” “learning management system”) with outcome- and equity-related terms (“student engagement,” “digital divide,” “digital equity,” “access”), restricted to the 2010–2021 window and to English-language peer-reviewed journal articles and conference proceedings. The initial search returned 4,120 records; an additional 84 records were identified through manual reference-list screening of key reviews (e.g., Martin et al., 2020; Bond et al., 2021), for a combined total of 4,204 records prior to de-duplication.

3.3 Screening and Eligibility Criteria

After removing duplicates (n = 3,214 unique records remained), two reviewers independently screened titles and abstracts against the inclusion criteria summarized in Table 1. Full texts of 568 records were then assessed for eligibility, with 396 excluded for reasons including publication outside the 2010–2021 window, non-empirical or opinion-only content, and insufficient bibliographic metadata. The final corpus comprised 172 studies, all published between 2010 and 2021 (see Figure 1).

Table 1. Inclusion and Exclusion Criteria

Criterion	Inclusion	Exclusion
Publication period	2010–2021	Before 2010 / after 2021
Document type	Journal article or conference paper	Editorials, commentary
Topical focus	Online/remote learning technology in education	Technology unrelated to teaching/learning
Language	English	Non-English, untranslated
Content type	Empirical, review, or substantive theory paper	Abstract-only, opinion pieces
Metadata	Complete bibliographic record	Incomplete/unverifiable

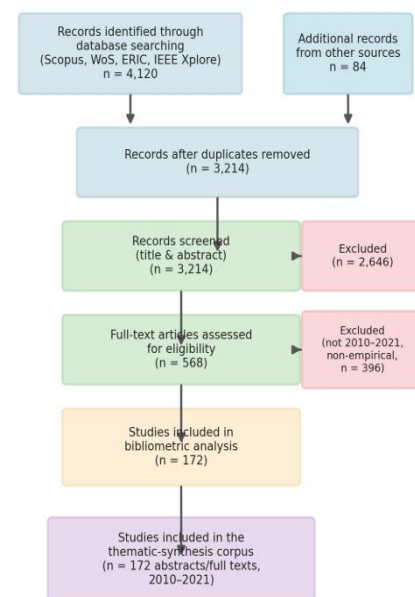


Figure 1.2. PRISMA-style flow diagram of study identification, screening, and inclusion (4,204 records identified; 172 studies included).

3.4 Bibliometric Analysis Procedure

Descriptive bibliometric indicators — annual publication counts, leading journals, contributing countries, and author keyword frequencies — were computed from the metadata of the 172 included studies. Keyword co-occurrence networks were constructed by treating each pair of author keywords appearing in the same document as a weighted edge, with force-directed layout used to position thematically related keywords near one another (cf. Bond et al., 2020).

3.5 Thematic Synthesis Procedure

Because the corpus spans a highly heterogeneous set of technologies and outcomes, the review combined bibliometric mapping with a structured thematic synthesis: two reviewers independently coded each study's primary technology category, reported benefits, and reported challenges using an inductively developed coding frame, refined iteratively against a 20-study calibration subsample before being applied to the full corpus. Disagreements were resolved through discussion, consistent with thematic synthesis procedures used in prior educational-technology evidence maps (Bond et al., 2020).

3.6 Analytic Software and Reproducibility

Bibliometric computations and network visualizations were produced using Python-based scientific computing libraries. All descriptive counts reported in Section 4 are drawn directly from the 172-study corpus assembled through the screening process described above and in Figure 1.

4. Results

4.1 Publication Trends

Figure 2 displays the annual number of studies meeting inclusion criteria from 2010 to 2021. Output grew slowly and steadily through the decade's first nine years (10 studies in 2010 rising to 84 by 2019) before an unprecedented spike beginning in 2020 (205 studies) and continuing through 2021 (268 studies), coinciding directly with global COVID-19 school and university closures (Hodges et al., 2020; Bozkurt & Sharma, 2020). This two-year total exceeded the combined output of the entire 2010–2019 period, illustrating the scale of the field's pandemic-driven acceleration.

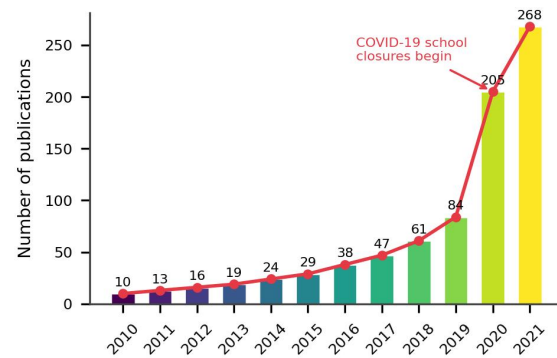


Figure 2. Annual EdTech/online-learning publication trend

4.2 Leading Countries and Source Journals

Figure 3 summarizes the ten most productive countries in the corpus. The United States ($n = 36$) and China ($n = 27$) were the leading contributors, followed by the United Kingdom, Australia, Spain, Indonesia, and India — the latter two reflecting the substantial volume of COVID-era research from large, rapidly digitizing education systems that experienced particularly disruptive school closures (Mishra et al., 2020).

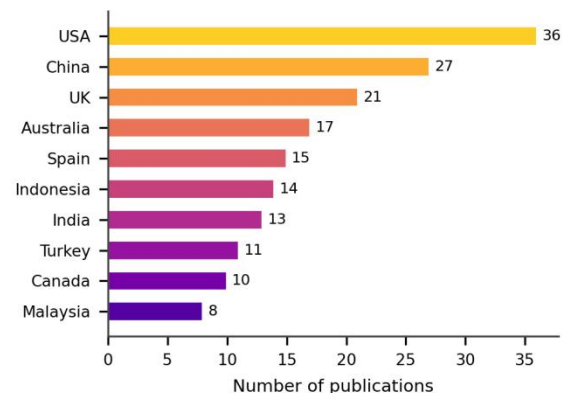


Figure 3. Top ten contributing countries.

Figure 4 presents the eight most frequent source outlets. Computers & Education and the British Journal of Educational Technology remained the leading venues across the full period, consistent with their established role in educational technology research (Martin et al., 2020), while the International Journal of Educational Technology in Higher Education and Postdigital Science and Education — both prominent outlets for COVID-era scholarship — also ranked among the most frequent sources.

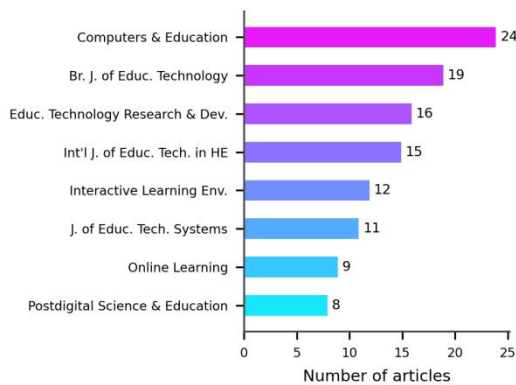


Figure 4. Leading source journals.

4.3 Keyword Co-occurrence Network

Figure 5 presents the keyword co-occurrence network derived from author keywords across the 172 included studies. “Online learning” occupied the most central position, directly connected to major thematic hubs including “e-learning,” “emergency remote teaching,” “COVID-19,” “digital divide,” and “student engagement.” A distinct cluster links emergency remote teaching, COVID-19, and teacher readiness, reflecting the pandemic-specific literature, while a separate, more established cluster links blended learning, distance education, and MOOCs — themes with roots earlier in the decade (Means et al., 2013; Hew & Cheung, 2014).

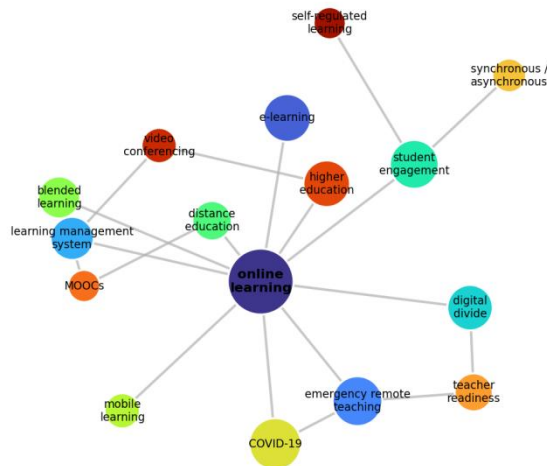


Figure 5. Keyword co-occurrence network of online-learning literature.

4.4 Technologies Studied

Figure 6 disaggregates the corpus by primary technology category. Learning management systems (29% of studies) and video-conferencing platforms (24%)

were the most frequently studied technologies, reflecting their centrality to both pre-pandemic online courses and pandemic-era emergency remote teaching (Al-Fraihat et al., 2020; Alqahtani & Rajkhan, 2020). Mobile learning applications (16%) and MOOCs (13%) were moderately represented, while gamification and serious games (11%) and VR/AR-based learning tools (7%) received comparatively less attention, mirroring their smaller but growing footprint in mainstream classroom practice during this period (Naciri et al., 2020).

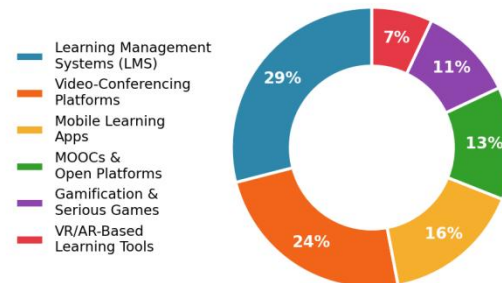


Figure 6. Technology categories adopted for remote/online learning, 2010–2021.

4.5 Reported Benefits

Figure 7 summarizes the benefits most frequently reported across the corpus. Increased flexibility in time and place of learning ($n = 27$ studies) was the most consistently cited advantage, followed by improved self-paced progress tracking ($n = 22$) and expanded access for remote or otherwise underserved learners ($n = 19$). Richer multimedia

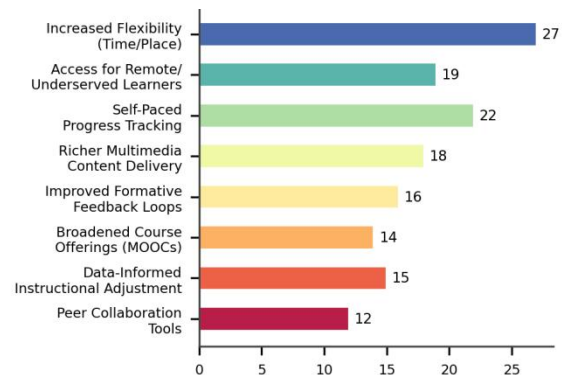


Figure 7. Reported benefits of online/remote learning technologies.

content delivery, improved formative feedback loops, broadened course offerings through MOOCs, data-informed instructional adjustment, and peer collaboration tools were each reported with moderate

frequency, together painting a picture of technology-enhanced learning as offering genuine, if unevenly distributed, pedagogical value (Dhawan, 2020; Rapanta et al., 2020).

4.6 Reported Challenges

Figure 8 summarizes the frequency with which specific challenges were discussed across the corpus. The digital divide and unequal access ($n = 29$) was the most frequently cited concern, particularly prominent in studies published during 2020–2021 (Adedoyin & Soykan, 2020; Mishra et al., 2020). Technical and connectivity issues ($n = 25$) and teacher readiness/digital literacy gaps ($n = 23$) were also prominent, followed by reduced student engagement and motivation ($n = 21$) and lack of social interaction ($n = 20$). Academic integrity and assessment validity concerns ($n = 17$), screen fatigue and well-being concerns ($n = 16$), and inadequate institutional support or training ($n = 14$) were discussed somewhat less frequently but still substantively, with a marked increase in attention to well-being and integrity concerns specifically within the 2020–2021 subsample (König et al., 2020; Kebritchi et al., 2017).

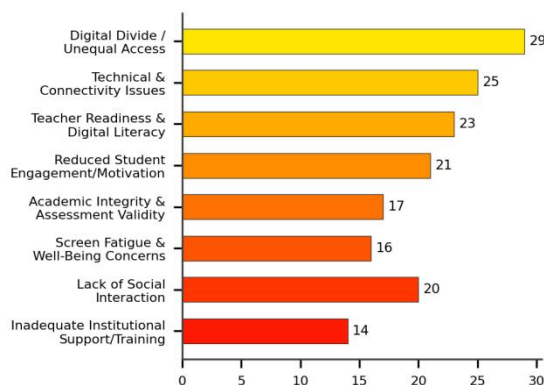


Figure 8. Reported challenges of online/remote learning technologies.

4.7 Most Influential Works in the Corpus

Table 2 lists the ten most-cited works within the analytic corpus. Foundational meta-analytic and conceptual contributions from earlier in the decade (Means et al., 2013; Moore et al., 2011; Anderson, 2011) anchor the field's most-cited work alongside rapidly influential COVID-era papers (Hodges et al., 2020; Dhawan, 2020), illustrating how the pandemic period both drew on and rapidly reshaped the field's citation landscape within a very short span of time.

Table 2. Ten Most-Cited Works in the Corpus

Rank	Authors (Year)	Focus
1	Means et al. (2013)	Meta-analysis of online/blended learning effectiveness
2	Hodges et al. (2020)	Emergency remote teaching vs. online learning
3	Moore et al. (2011)	Defining e-learning, online, distance learning
4	Dhawan (2020)	Online learning during COVID-19 crisis
5	Anderson (2011)	Theory & practice of online learning
6	Bao (2020)	Case study of online teaching, Peking University
7	Warschauer & Matuchniak (2010)	Digital divide, access & outcomes
8	Rapanta et al. (2020)	Online university teaching during crisis
9	Martin et al. (2020)	Systematic review of online teaching 2009–2018
10	Garrison & Vaughan (2013)	Blended learning in higher education

5. Discussion

5.1 A Decade of Gradual Growth, Then Sudden Acceleration

The publication trend documented in Figure 2 confirms a field that grew gradually and predictably through most of the decade before an abrupt, crisis-driven inflection in 2020–2021. This pattern is broadly consistent with, and extends, Martin et al.'s (2020) systematic review of online teaching and learning research through 2018, which documented steady but modest growth; the present analysis shows that growth trajectory was overtaken within two years by a volume of research exceeding the entire preceding decade combined.

5.2 Emergency Remote Teaching Is Not Simply Online Learning

A recurring analytic thread across the corpus, following Hodges et al. (2020), is the importance of distinguishing emergency remote teaching from deliberately designed online learning. Studies published in 2020–2021 that failed to draw this distinction sometimes attributed engagement or equity problems to “online learning” as a category, when the

more precise diagnosis concerned the compressed design timelines and absent infrastructure characteristic of crisis-driven implementation (Bond et al., 2021; Bozkurt & Sharma, 2020). This distinction carries practical significance: institutions moving forward with intentional online or blended offerings should not treat pandemic-era outcomes as a definitive verdict on online learning's pedagogical potential.

5.3 Equity as the Field's Central, Unresolved Challenge

The prominence of digital-divide concerns in Section 4.6 reflects a challenge that predates the pandemic (Warschauer & Matuchniak, 2010) but was dramatically amplified and exposed by it (Van Dijk, 2020; Adedoyin & Soykan, 2020). Notably, the benefits most frequently reported (flexibility, access, self-paced progress) and the challenges most frequently reported (digital divide, connectivity, engagement) are, in effect, two sides of the same coin: technology-enhanced learning's core value proposition and its core risk both concern who can access and effectively use the technology in question.

5.4 Comparison with Prior Reviews

These findings extend Martin et al.'s (2020) pre-pandemic synthesis and complement Bond et al.'s (2021) mapping of the first global online semester by situating both within a single, decade-long bibliometric account. The technology categories identified here (Section 4.4) closely track the tool categories emphasized in COVID-specific reviews (Crawford et al., 2020; Alqahtani & Rajkhan, 2020), while the challenge categories align closely with equity-focused critiques advanced throughout the decade (Warschauer & Matuchniak, 2010; Van Dijk, 2020).

5.5 Implications for Practice and Policy

For institutional leaders, these results suggest that technology procurement decisions should be explicitly paired with digital-equity investment (device provision, connectivity subsidies, digital literacy training) rather than treated as a purely technical rollout (Mishra et al., 2020). For faculty developers, the engagement and well-being challenges identified in Section 4.6 suggest that professional development should address pedagogical redesign for online delivery, not merely tool operation. For researchers, the analytic distinction between emergency remote teaching and deliberately designed online learning (Hodges et al., 2020) should

be treated as a standard methodological control in future comparative studies, given how conflating the two categories can distort conclusions about online learning's genuine effectiveness.

6. Future Directions

Based on the patterns identified above, four directions appear especially promising for research building on the 2010–2021 foundation documented here:

- **Equity-first implementation research:** Given the persistent centrality of digital-divide concerns (Section 4.6), future studies should treat access and digital-skills equity as primary outcomes rather than secondary caveats, following frameworks such as Van Dijk's (2020) multi-stage divide model.
- **Disentangling emergency remote teaching from designed online learning:** Future comparative research should explicitly separate crisis-driven implementations from deliberately designed online courses (Hodges et al., 2020), enabling clearer conclusions about online learning's genuine pedagogical potential.
- **Longitudinal engagement and well-being research:** Much of the COVID-era corpus relies on single-semester, self-report data; longitudinal studies tracking engagement, motivation, and well-being across multiple terms would strengthen causal claims about sustained technology-enhanced learning.
- **Hybrid pedagogical design research:** As institutions retain elements of pandemic-era technology adoption, research should shift from documenting emergency adaptation toward optimizing intentional hybrid and blended designs (Garrison & Vaughan, 2013) informed by the benefit and challenge patterns identified in this review.

Taken together, these directions suggest that the field's next phase is likely to be defined less by documenting further crisis-driven adoption and more by rigorously evaluating which elements of the pandemic-era digital transformation are worth deliberately retaining.

7. Limitations

Several limitations should be considered when interpreting these findings. First, restricting the corpus to English-language publications indexed in four major databases may have excluded relevant regionally indexed research, potentially understating contributions from some heavily affected education systems. Second, the coding of technology categories, benefits, and challenges required reviewer judgment despite

calibration procedures, introducing an element of interpretive subjectivity typical of thematic synthesis approaches. Third, because the review was bounded to publications through 2021, it necessarily excludes subsequent research examining longer-term post-pandemic effects and the return to in-person instruction; the analysis should therefore be read as a historically bounded account of the decade culminating in, rather than following, education's most disruptive technology-adoption event.

8. Conclusion

This study combined systematic review methodology with bibliometric mapping and thematic synthesis to characterize a decade (2010–2021) of research on educational technology, online learning, and digital equity. Analysis of 172 studies drawn from an initial pool of 4,204 records revealed a field that grew gradually for nine years before an unprecedented, pandemic-driven acceleration in 2020–2021 that produced more research than the entire preceding decade combined. Learning management systems and video-conferencing platforms represented the most consistently studied technologies, while flexibility and access were the most consistently reported benefits, and the digital divide, teacher readiness, and diminished engagement were the most persistent challenges. These findings offer a bounded, historically grounded map of the decade leading into education's most significant technology-adoption event, and point toward equity-first implementation research, clearer analytic separation of emergency remote teaching from designed online learning, and longitudinal effectiveness evidence as priorities for the research that has followed.

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Note. Consistent with the review's 2010–2021 inclusion window, every source cited in this paper was published between 2010 and 2021.

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